Range Commanders Council

OPTICAL SYSTEMS GROUP

DOCUMENT 451-00

PHOTOGRAPHY, MOTION PICTURE FILM CORES AND SPOOLS, PERFORATIONS, AND OTHER TECHNICAL INFORMATION

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KWAJALEIN MISSILE RANGE
YUMA PROVING GROUND
DUGWAY PROVING GROUND
ABERDEEN TEST CENTER
NATIONAL TRAINING CENTER

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AIR FORCE FLIGHT TEST CENTER
AIR ARMAMENT CENTER
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ARNOLD ENGINEERING DEVELOPMENT CENTER
GOLDWATER RANGE
UTAH TEST AND TRAINING RANGE

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The information contained in this document is intended to provide a means of more rapidly identifying most of the cores and spools used throughout the motion picture industry. No attempt has been made to identify all of the various items that are available, but rather to list those items most widely used.

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JANUARY 2000

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TABLE OF CONTENTS

ABSTRACT

The information in this document is intended to provide a means of more rapidly identifying most of the cores and spools used throughout the motion picture industry. No attempt has been made to identify all of the various items that are available, but rather to list those items most widely used. Manufacturers' data sheets and/or pamphlets covering this subject for their respective products can be obtained from the specific manufacturer. The pamphlets that apply are Eastman Kodak "16mm, 35mm, and 70mm Films," Pamphlet #P-29 and Photo-Sonics technical data sheets.

SECTION I

INTRODUCTION

The purpose of this document is to present camera technical information and representations of the types of film cores and spools that are currently available on the open market. At the present time, only one company, Eastman Kodak, is supplying the test range industry with these film products. Specific technical information about these products appears in this publication. Additionally, information is included that may be of value to data reduction analysts.

Also provided herein are representations of special cores and spools that are required specifically for high-speed camera use. These specially manufactured devices are designed to withstand the torque generated in high-speed camera operations. In addition to the identification of these cores and spools, an attempt has been made to provide technical information regarding flange focal distances, timing displacement, aperture openings for cameras, and light transmission for prism cameras.

Appendix A of this document contains reprints of cores and spools information that was taken from Kodak Publication P-29. Pictured in appendix B are special cores and spools. Reprints of items relating to film perforation, dimensions, and usage are at appendixes C and D. Specifically, appendix C contains a tutorial on the history, standardization, and usage of various motion picture perforations and the Index to Society of Motion Picture and Television Engineers (SMPTE)-Sponsored American Standards. Appendix D features reprints of two American Standard Dimensions for film perforations. Lastly, reprints of perforation and film dimensions, also taken from Kodak Publication P-29, are in appendix E.

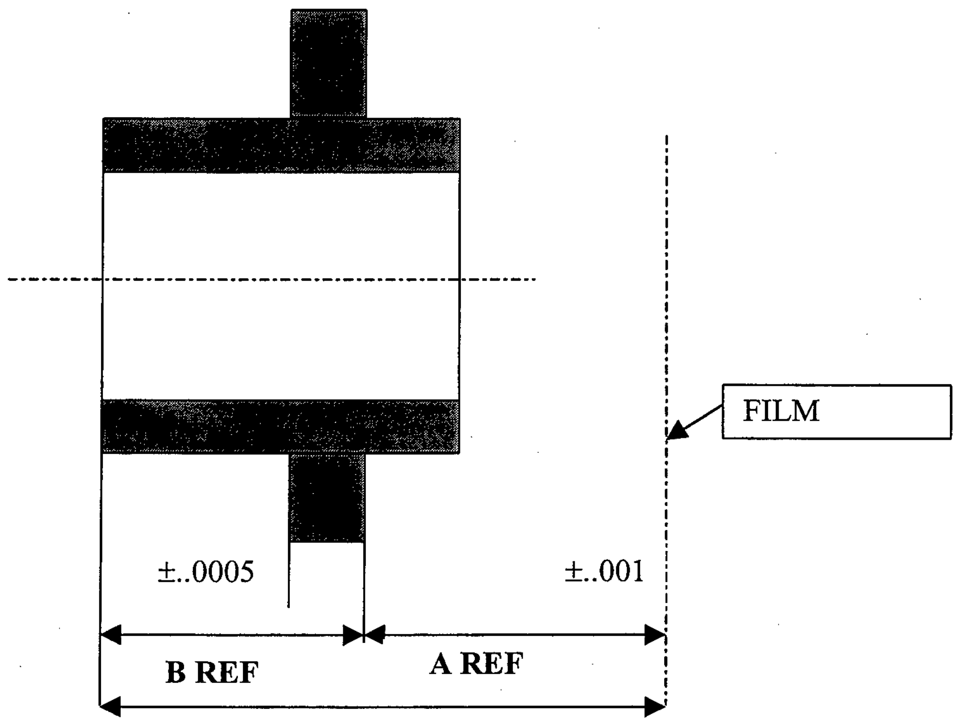
It is recommended that this document be used as an outline to which the user can add the latest information as it becomes known or available.

SECTION II

FLANGE FOCAL DISTANCES

The information provided in this section could be used to manufacture lens adapters when such adapters are unavailable on the open market. The cost-cutting environment in which the ranges currently operate necessitates varying the use of the present inventory of lenses to meet customer requirements. Most test sites have lenses in their inventory that can be adapted for use on a variety of cameras. An example is the Mamiya M-645, which is normally used with the 16mm Photec V. This lens can be adapted to the Photo-Sonics 4ML and the 4B/4C. With the provided flange focal distances, an adapter can be locally manufactured for these cameras. This configuration produces a very acceptable image as well as good light transmission.

With this information and a real need to use available lenses, a mechanical engineer should be able to implement the local manufacture of an acceptable adapter. The manufacturers of high-speed photographic equipment have shown an interest in the production of these adapters if the development and test prove profitable and a need exists.



NOTES:
1. All dimensions are at infinity
2. "C" Mount dimension .690 (16mm)
3. "D" Mount dimension .484 (8mm)
4. GSAP Mount dimension 1.0185 (16mm)

PHOTO-SONICS, Incorporated, 1994, Burbank, California.

Back Focus or Flange Focal Distance of Camera Models Currently Used

16MM

MODEL NO.	A REF	B REF	C REF
-1B	1.796		
-1F	1.635		
Model 6 Thin turret	1.218		
1C	1.796		
1D	1.891		
1E	0.905		
1P	0.69		
1PDL			2.047

35MM

MODEL NO.	A REF	B REF	C REF
4B-4C	2.274	0.678	2.953
Hasselblad Mount 4B-4C	2.274	0.96	3.234
4E/6E	2.274	0.678	2.953
4M/ML	1	1.953	2.953
Model 5	2.312		
Model 6	2.375	.579	2.953
Mamiya			2.4803
Pentax			1.793

70MM

MODEL NO.	A REF	B REF	C REF
-10M			3.346
-1B	1.938	1.015	2.953
Hasselblad-5C	1.938	1.296	3.234
-5C	1.625		
-10A	1.938		
Illum. Fiouc.-10A	2.25	0.703	2.953
-10B	4.594		
-5B	1.938		
-10D	1.5		
-10P	2.25	0.702	2.953
-10R	4.594		
-14			3.347

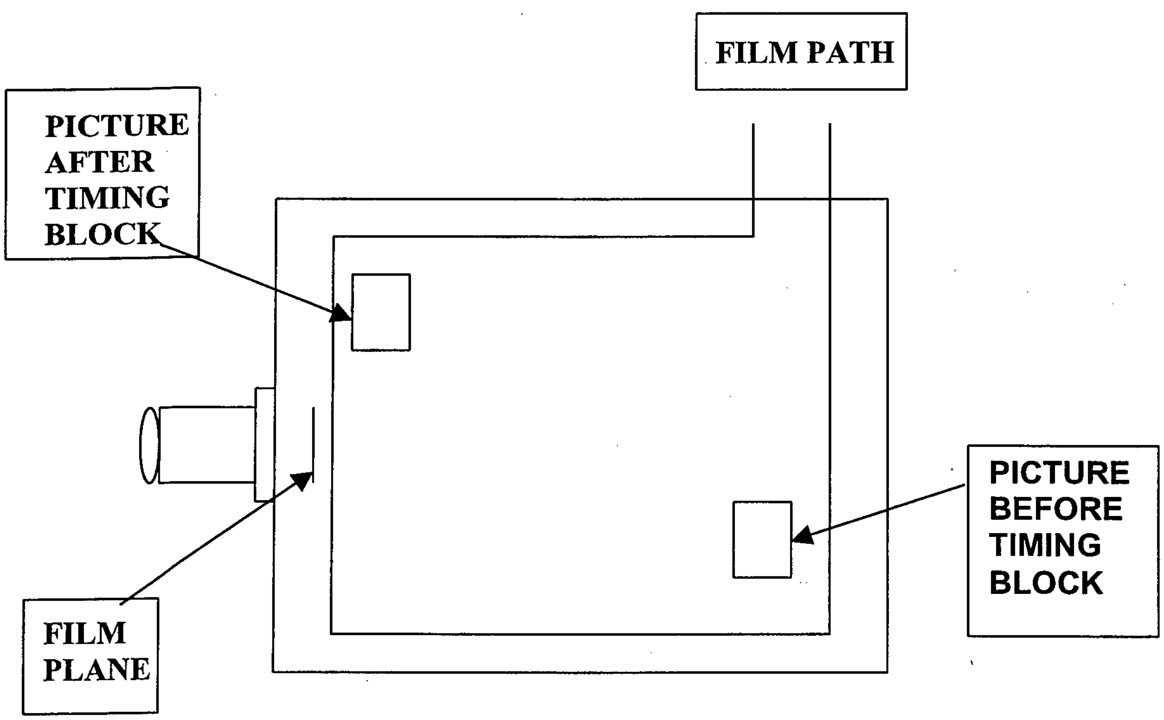
PHOTO-SONICS, Incorporated, 1994, Burbank, California.

SECTION III

TIMING DISPLACEMENT

This section contains information primarily of value in the data reduction process. Although the Film Data Recording System (FDRS) has reduced side serial timing to some degree, film edge timing continues to be widely used by the test ranges. Information of this sort is often requested by projects to facilitate their individual data reduction efforts.

Timing Displacement in Reference to Picture



CAMERA INFORMATION FOR TIMING DISPLACEMENT AT THE TIME THE PICTURE IS BEING EXPOSED, TIME IS BEING PRINTED ON FILM

TYPE CAMERA	DISPLACEMENT
FASTAX WF4S, 16mm	5 perforations before
FASTAX WF3, 16mm	5 perforations before
NOVA-FULL, HALF, & QUARTER FRAME, 16mm	3 perforations before
MILLIKEN, 16mm	13 perforations after
REDLAKES FASTAX II	3.4 perforations after
PHOTEC IV, 16mm	4.5 perforations before
REDLAKES HYCAM, 16mm	5 perforations after
REDLAKES LOCAM, 16mm	26.5 perforations after
PHOTO-SONICS 1PL, 16mm	13 perforations after
FASTAX WF5, 35 mm	8 perforations before
FASTAX WF5, HALF FRAME, 35mm	8 perforations before
DUMONT STREAK, 35mm	7 perforations before
MITCHELL, 35mm	58 perforations before
REDLAKES HYTAX, 35mm	0 perforation
PHOTO-SONIC 4B, 35mm	66 perforations before
PHOTO-SONIC 4C, 35mm	44 perforations before
PHOTO-SONIC 4E, 35mm	52 perforations before
PHOTO-SONIC 4ML, 35mm	7.5 perforations before
PHOTO-SONIC 10B, 70mm	75 perforations before
PHOTO-SONIC 10A, 70mm	4 perforations after
PHOTO-SONIC 10RL	5.5 frames before
PHOTO-SONIC 14S	14 perforations before
CZR	0 frames
1VN	10 frames after

SECTION IV

APERTURE OPENINGS FOR CAMERAS

Although the standards of the American Standards Association are adhered to by most camera manufacturers, some variations in the aperture openings of high-speed cameras may exist. As a rule, these variations do not normally pose problems. However, in scientific photography, aperture openings are critical in computing the field of view. The information that follows is provided to aid in the computation process for critical fields of view.

Aperture Openings for Cameras

16MM*	35MM*	70MM*
1PDL - .296" x .410"	6EL- 1.000" x 1.000"	14S- 2.250" x 2.500"
1VN - .296" x .552"	4ML- 0.745" x 0.995"	10RL – 2.250" x 2.250"
1PL - .296" x .410"	4EL - 0.724" x 0.986"	10B - 2.250" x 2.250"
1B - Full frame 16mm	4BL/4CL - 0.745" x 0.995"	10A - 2.250" x 2.250"
Locam - 0.292" x 0.410"	4B/4C - 0.745" x 0.995"	

*Note: Film data recording systems may change aperture opening. Check with manufacturer/manual for this information.

SECTION V

LIGHT TRANSMISSION OF PRISM CAMERAS

Knowledge of actual light transmission of prism cameras is only required when the light transmission of the camera is less than the light transmission capability of the lens. An example would be to use an f/1.5 lens with a camera that will only allow an f/3.2 light transmission. Any setting on the lens greater than f/3.2 would be negated by the camera.

ACTUAL LIGHT TRANSMISSION OF PRISM CAMERAS IN USE

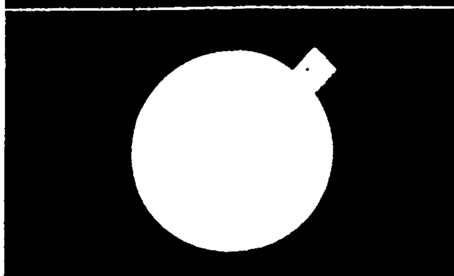
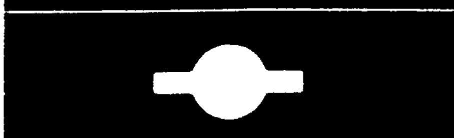
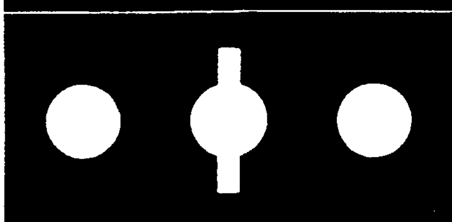
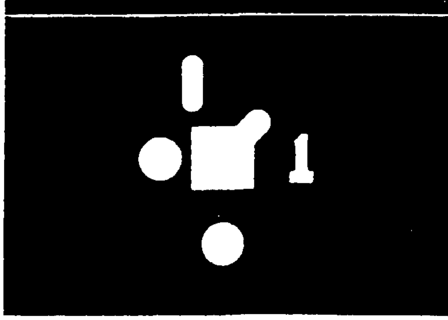
16MM	**35MM**	**70MM**
PHOTEC V: f/2.8	4B/4C: f/1.9	10B: f/2.2
FASTAX II: f/2.7	4BL/4CL: f/1.9	
WF4S: f/2.7		
HYCAM: f/3.2		

APPENDIX A

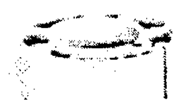
CENTER HOLE SPECIFICATIONS, CORES AND SPOOLS

The following excerpts are reproduced by permission of Eastman Kodak Company. Copies of publication P-29, Technical Data of Film Specification Numbers, Spools, Cores, Dimensions and Perforations, may be obtained from Eastman Kodak Company, Department 454, 343 State Street, Rochester, New York 14650.

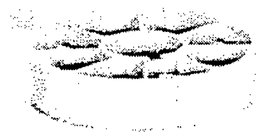
CENTER HOLE SPECIFICATIONS

CONFIGURATION	SPOOL OR CORE	DESCRIPTION
	Type AA	0.320-inch square center hole with keyway
	Type J	0.324-inch square center hole
	Types R, S, T, U, X, Z	1-inch round center hole with keyway. Note: Type R Core has a key which extends halfway through the center hole
	S-146, S-147, S-148, S-149	0.385-inch round hole with double keyways
	S-65, S-184, S-151	0.385-inch round center drive hole with double keyways and two round drive holes 0.379-inch diameter
	S-83, S-84, R-90, S-101, S-153	0.320-inch square hole with keyway
	R-190	0.320-inch square hole with keyway and two offset round drive holes. One elliptical hole and side 1 and side 2 markings

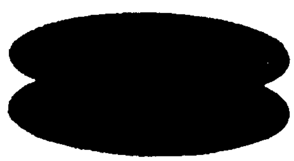
CORES AND SPOOLS, 16 mm



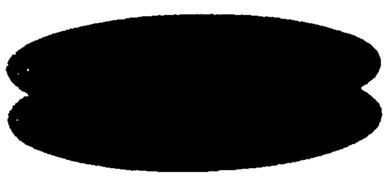
Type T Core—2-in. O.D., 16 mm. Round center hole with keyway. With film slot.



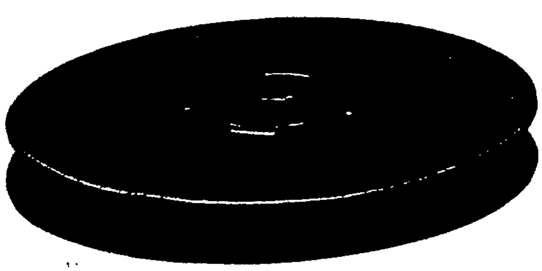
Type Z Core—3-in. O.D., 16 mm. Round center hole with keyway. With film slot.



R-90 Spool—16 mm x 100 ft, flange diameter 3.615 in., core diameter 1¼ in. Square hole with keyway in both flanges.*



R-190 Spool—16 mm x 200 ft, flange diameter 4.940 in., core diameter 1¼ in. Square hole with keyway and two offset round drive holes and one elliptical hole in both flanges.* Side 1 and side 2 markings.



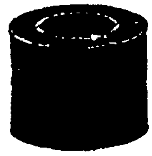
S-153 Spool—16 mm x 400 ft, flange diameter 6.625 in., core diameter 2⅛ in. Square hole with keyway in both flanges.*

*Center hole configuration aligned on both flanges.

(One foot = .305 metres)

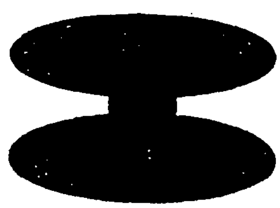
CORES AND SPOOLS, 35 mm
(Continued)

Type AA Core—1-in. O.D., 35 mm. Square center hole and keyway. With film slot.

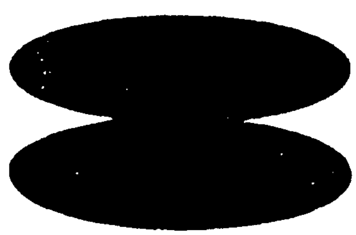


Type R Core—2-in. O.D., 35 mm. Round center hole with key extending halfway through center hole. With film slot.

Type U Core—2-in. O.D., 35 mm. Round center hole and keyway. With film slot.



S-83 Spool—35 mm x 100 ft, flange diameter 3.657 in., core diameter 31/32 in. Square hole and keyway in both flanges.*

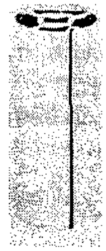


S-101 Spool—35 mm x 200 ft, flange diameter 4.625 in., core diameter 31/32 in. Square hole with keyway in both flanges.*

*Center hole configuration aligned on both flanges.

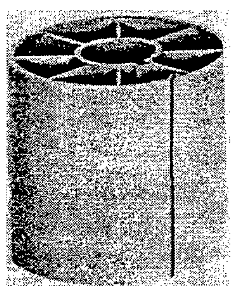
(One foot = .305 metres)

CORES AND SPOOLS, 70 mm
(Continued)



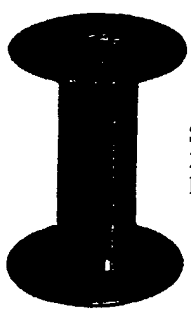
Type J Core—1¼-in. O.D., 70 mm. Square center hole. With film slot.

Type X Core—2-in. O.D., 70 mm. Round center hole and keyway. No film slot.

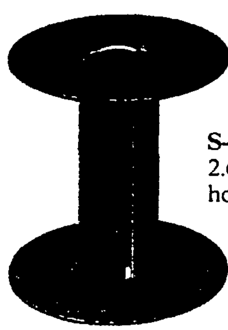


Type S Core—3-in. O.D., 70 mm. Round center hole and keyway. With film slot.

S-146 Spool—70 mm x 15 ft, flange diameter 1.719 in., core diameter 31/32 in. Round center hole with double keyways in both flanges.



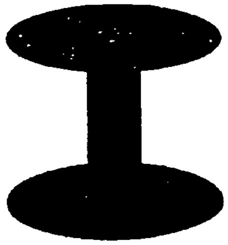
S-147 Spool—70 mm x 25 ft, flange diameter 2.125 in., core diameter 31/32 in. Round center hole with double keyways in both flanges.



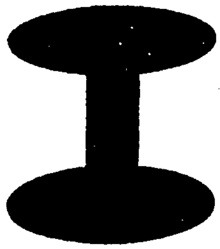
S-148 Spool—70 mm x 50 ft, flange diameter 2.625 in., core diameter 31/32 in. Round center hole with double keyways in both flanges.

(One foot = .305 metres)

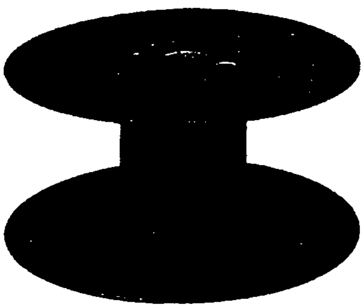
CORES AND SPOOLS, 70 mm
(Continued)



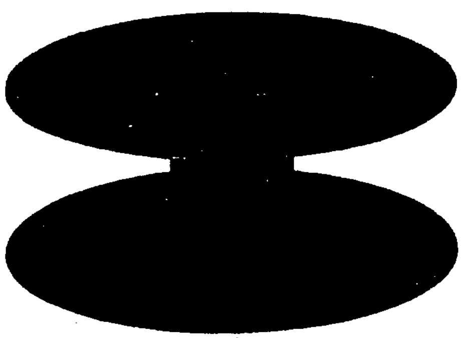
S-149 Spool—70 mm x 100 ft, flange diameter 3.750 in., core diameter 31/32 in. Round center hole with double keyways in both flanges.



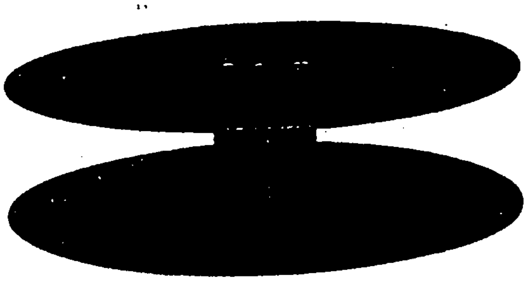
S-84 Spool—70 mm x 100 ft, flange diameter 3.657 in., core diameter 31/32 in. Square hole with keyway in both flanges.*



S-150 Spool—70 mm x 250 ft, flange diameter 5.938 in., core diameter $2^1/_8$ in. Round center drive hole with double keyways and two round drive holes in both flanges.



S-151 Spool—70 mm x 500 ft, flange diameter 7.625 in., core diameter $2^1/_8$ in. Round center drive hole with double keyways and two round drive holes in both flanges.



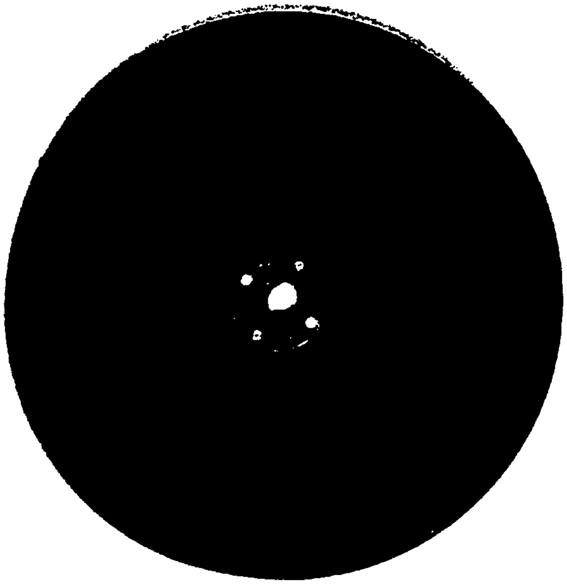
S-65 Spool—70 mm x 1000 ft, flange diameter 10.500 in., core diameter $2^1/_8$ in. Round center drive hole with double keyways and two round drive holes in both flanges.

*Center hole configuration aligned on both flanges.

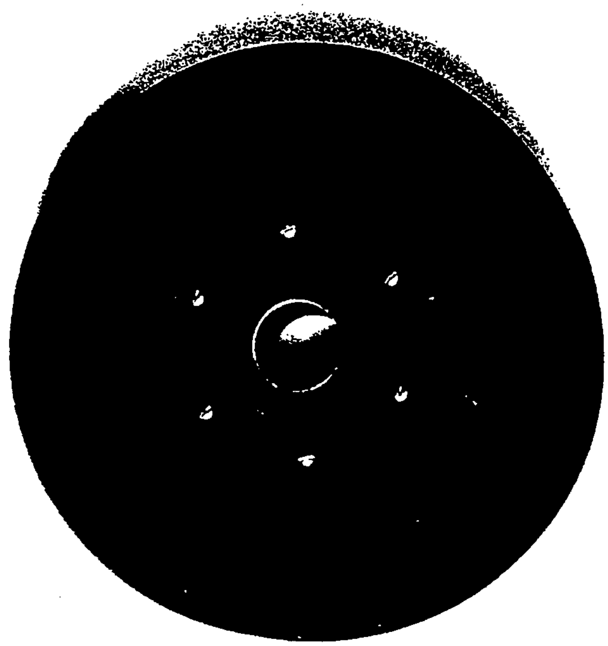
APPENDIX B

SPECIAL CORES AND SPOOLS

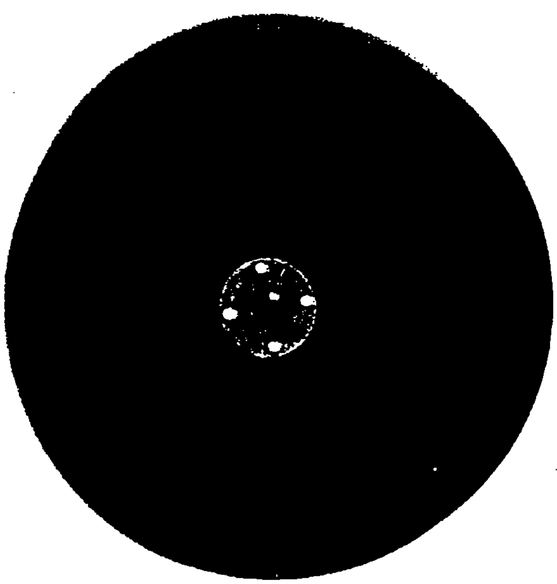
SPECIAL SPOOLS AND CORES
for
Photo-Sonics Cameras



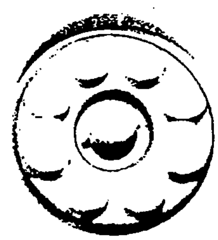
P/S 1PL 1200' Spool 16mm



P/S 10B 1200' Spool 70mm



P/S 4ML 1200' Spool 35mm



P/S 4B/4C High Speed Core 35mm

APPENDIX C

SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS (SMPTE)

The following reprints are reproduced by permission of the SMPTE. Additional copies may be obtained from SMPTE Headquarters, 9 East 41st Street, New York, N.Y. 10017.

Motion-Picture Film — Its Size and Dimensional Characteristics

A TUTORIAL PAPER

By A. J. MILLER
and A. C. ROBERTSON

The dimensions of motion-picture film and the shapes of perforations have followed a logical development over 30 or more years. Traced here is some of this history, so that we can better understand why the American Standards Association recognizes certain standards today. For example, the need for accurate printing processes has led to the introduction of dimensional standards with close tolerances. Improvements in the plastics of which film supports are made, coupled with the use of continuous printers, have led to the introduction of standards which discriminate between products differing only by 0.2% in one dimension, since that small difference is recognized as an important matter in the economical attainment of good quality in printing. Other industry demands have been met over the years: e.g., today's CS perforation (introduced to meet the needs of the CinemaScope development in wide-screen presentation) gives more available area for soundtracks. Also, the 16mm film used today is manufactured slightly narrower than that of earlier years because of improved dimensional stability of the base. Furthermore, the needs of other processes involving films with widths varying from 8mm to 70mm have been recognized in various new standards. It is expected that there will be further changes as the industry develops.

Introduction

The purpose of this article is to describe the various forms of perforated film used in motion-picture photography with respect to their history, their standardization, and their usage. There are films of many sizes described in the Index of Standards published annually in the December issue of the *Journal of the SMPTE*. The standards in question describe the dimensions of the films, but do not give a complete background of the origins of the various formats, the way in which they fit a current need, and the relationship to the other formats which may appear to be similar.

It is very difficult for people wanting to do new things to know which is the film of the best size and perforation type that will best suit their needs. In fact, these people may not know what kinds of films are available. Knowledge of this kind is needed to help designers new to the field and at the same time refresh the memory of current practitioners. The required material is scattered so widely that it is prudent and economical to gather it in one place.[1]

In a few cases, such as international standardization, it is helpful also to

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Presented on October 15, 1963, to the SMPTE Film Dimensions Committee as a status report, and on September 29, 1964, to the Society's Technical Conference in New York by A. J. Miller, Du Art Film Laboratories, Inc., 245 W. 55 St., New York, N.Y. 10019, and A. C. Robertson, Eastman Kodak Co., Manufacturing Experiments Div., Bldg. 35, Kodak Park, Rochester, N.Y. 14650.
(This paper was received in final form on November 2, 1964.)

Reprinted from: January 1965 Journal of the SMPTE, Vol. 74, pp. 3–11 [1]

STANDARDS

ADOPTED BY THE

SOCIETY OF MOTION PICTURE ENGINEERS

FIRST EDITION

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Fig. 1. Cover of pamphlet published by the Society in 1917. It contained 17 titles of standards with brief data about each.

establish the chronological sequence of events, and the history of attempts at simplification. Note in this connection that the numbering of American standards is not sequential. At one time the numbers attached to standards were "used" again for other subjects. This means that the size of the identifying number does not necessarily help set the relative dates for the adoption of standards. Today, however, there is an effort being made to keep the same number for the same item when revisions are made.

When production started in motion-picture photography in the days when Eastman and Edison worked together in 1889, there was film of one size for positive and negative films. Indeed, for some time there was only one emulsion, and the problem of supply was simple for the photographer and the manufacturer alike. Of course, there were many formats (some of them larger) used in traveling exhibits. Most of these exhibits featured personal appearances, such as those of the lecturing traveller. Some shows were given by men who had previously been magicians. Mèliés and Victor[2] were the best examples. These men were more conscious of the show than of the engineering problems of standardization.

Motion-picture photography has grown and today the list of official standards contains 19 dimensional standards bearing the PH22 number which signifies that they relate to cinematography. Other standards relating to this field are being studied in committee. In addition to the number of film formats which have been recognized in an official sense, there are several specialized or variant formats that have not been officially standardized because they are not employed by enough users to require industry-wide approval. As for the types of emulsions employed, these number several dozen today and range from the relatively simple ones used in making the common black-and-white print stock to the rather unusual emulsions used for color camera-films, color intermediate materials and color print stocks.

There is a wide range of choice of motion-picture films available to the industry as a result of the many combinations of emulsion types, widths, perforations, and pitch dimensions. Accordingly, the question may arise about the need for such variety.

Positive and Negative Perforations

There are valid reasons for making film with perforations of different sizes and pitches. However, some film used

in the early days has changed little with respect to format and physical dimensions since Edison's time. The perforations in the earliest film had almost the same size and shape of the current "Bell & Howell" perforation described today by PH22.34-1956. The early film was described in a pamphlet on standardization (Fig. 1) published by the Society in 1917, very soon after the publication of its terms of incorporation and its Bylaws.[3] The perforations described in this booklet had well-defined corners where the round portions intersected the "flats," as shown in Fig. 2 and the lower part of Fig. 3. These corners were not rounded with a fillet and accordingly, the intersections could really be called sharp. As a result of the concentration of stresses permitted by this conformation, fractures were apt to occur in the corners after the film had been projected a few times.

The damage was caused in part by the design of some projectors made in the early twenties. These projectors had many desirable features that brought them into general use. Unfortunately, these projectors also had sprockets of unusual dimensions. The sprockets accentuated the problem caused by perforations which tore at the corners. This tearing came about because of "interference" between the perforations and the entering and leaving sprocket teeth as the film travelled over the sprocket. When the film is pulled forward by the front face of the tooth engaging the front edge of the perforation, and when the film is so short that the trailing edge of the perforation cannot slide down the back face of the entering sprocket-tooth, then the film must tear. The typical tear starts in the comparatively sharp corner of the perforation where the "flat" joined the circular sides.

As a result of unfavorable factors, especially interference, the projection life of the film was sometimes shorter than desired. In 1923, J. G. Jones[4] corrected most of the difficulties concerning the life of the film by devising the style of perforation still used for 35mm black-and-white release prints. This perforation was rectangular, with rounded corners. His recommendations for the improved style of perforation were proposed in 1923 and adopted by the Standards Committee of the Society in 1928. The primary change was an increase in height of the perforation from 0.073 in. to 0.078 in. This modification was a compromise that made it possible for print film to operate as well in one projector which possessed unusual and actually undesirable design characteristics as in all other projectors. The leeway added by the heightened perforation removed the interference that had caused trouble. Also, the adoption of the rounded corners in the perforation, as shown in PH22.36-1954, was effective in decreasing the stresses in the corners to a safe value. Here we have a special effort aimed at making projectors do

Film perforation—The dimensions and location of film perforation shall be in accord with the illustrating diagram herewith.

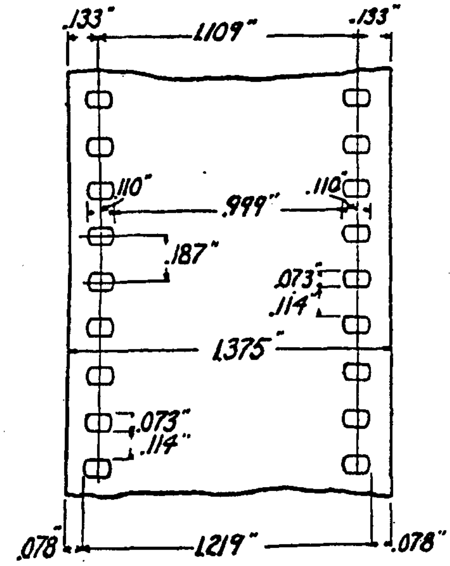


Fig. 2. Dimensions for 35mm film as shown in the pamphlet on Standards published by the Society in 1917.

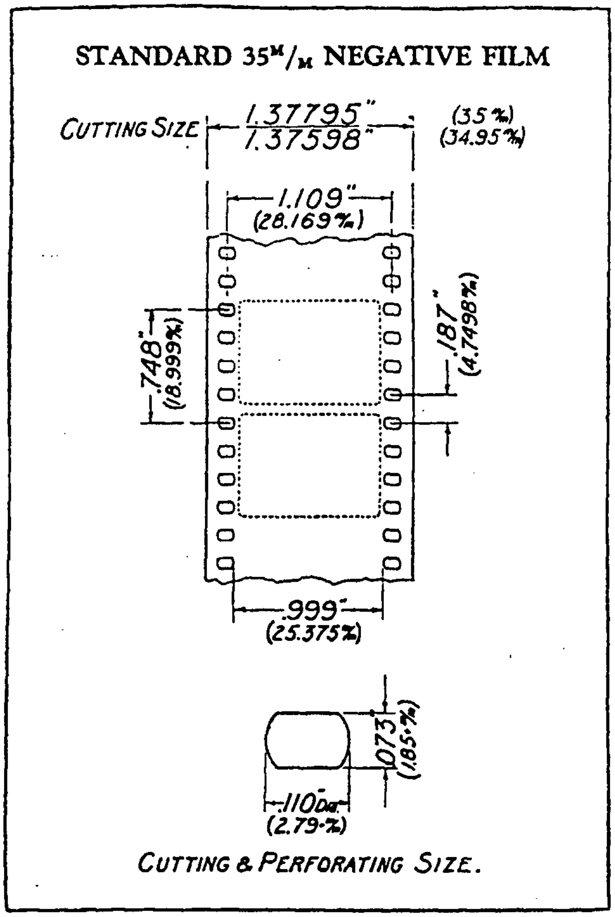


Fig. 3. Dimensions for 35mm film as given in 1930.

their best. At that time, even with the addition of another shape of perforation, the supply problems were still fairly easy. In 1923, there were only seven emulsion types used for motion-picture purposes.[5]

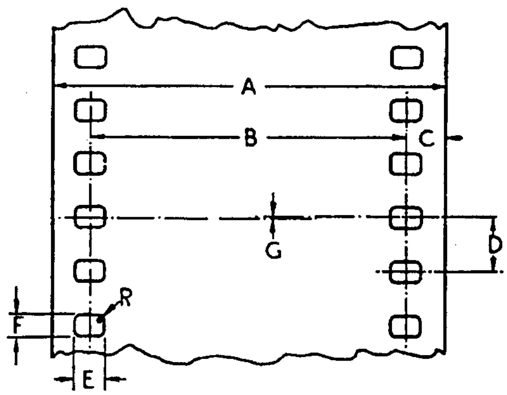
Process Photography

The earliest motion-picture photography was completely straightforward and simple. Complications appeared later with greater use of "process photography" of the inconspicuous kind. At first, process photography was used to produce imaginative scenery or effects, (used as early as 1904 by George Mèliés[6]) also, producers made ghost pictures by double exposure. In a similar way they portrayed people who had such a resemblance to each other that they were regarded as doubles. Sometimes the adventures of twins were recorded in romantic pictures. It was realized later that process photography could be used for other purposes. It was found that realistic background could be printed in by laboratory operations with a process printer, or photographed on the stage by using a regular camera and by having the actors appear in front of a projected image on a translucent screen. These procedures had several advantages, particularly in cost reduction. These operations diminish the need to go on location or to build expensive sets. Process printing and background projection are two techniques included under the general designation of "special effects" photography. Most of these techniques require great accur-

STANDARD 35-MM. FILM

CUTTING AND PERFORATING DIMENSIONS OF NEGATIVE AND POSITIVE RAW STOCK

These dimensions and tolerances apply to the material immediately after cutting and perforating.



	Inches	*Millimeters*
A	1.378 + 0.000 − 0.002	35.00 + 0.00 − 0.05
B	1.109 ± 0.002	28.17 ± 0.05
C	0.134 ± 0.002	3.40 ± 0.05
D	0.187 ± 0.0005	4.75 ± 0.013
E	0.110 ± 0.0003	2.79 ± 0.008
F	0.078 ± 0.0003	1.98 ± 0.008
G	Not > 0.001	Not > 0.025
R	0.020 approx.	0.51 approx.
*L**	18.70 ± 0.015	475.0 ± 0.381

* *L* = the length of any 100 consecutive perforation intervals.

Fig. 4. Dimensions for 35mm film, both positive and negative, as given in 1934.

acy in the perforating of the film in order to keep at a low value the relative motion between parts of the picture printed at various times. It takes very little relative motion to impair the illusion. Few descriptions of these processes were published before 1928. There have been good descriptions of the traveling matte procedure and other types of process photography since then. A recent article[7] gives a good historical view of the use of these procedures when the industry was young and Norman Dawn was active in devising new schemes. A number of more detailed discussions[8–12] have also been published.

Dawn found that he could not get the requisite accuracy in positioning with most of the cameras available in his day. In 1914, however, a camera with pins fixed solidly to the gate became available, and as a result the reproducibility of positioning the film, necessary for composite photography, became possible. This style of construction is still used today in some cameras. The exact placement of film for successive exposures depends upon the solidity of the registering pins, but it also depends upon the size of the perforation.[13]

The accuracy needed in the control of hole size is exemplified by the tolerances. They are the smallest specified in the standards. Even with good control, it is prudent to make the pins of a process camera larger (and therefore more snugly fitting) than the pins in a studio camera. The studio camera must not

make noise, as it might with snugly fitting pins, and so, a small and almost negligible risk of encountering unsteadiness is taken by using pins of nominal size.

Search for Accuracy

In spite of the secrecy that surrounded the details of process photography in its early days, film manufacturers were aware that film used for some special operations needed to be perforated more accurately than ever before. Accordingly, the standards were changed so that they indicated tolerable departures from the expected value for some dimensions. Compare Fig. 2 with Fig. 3, which was attached to the report of the Standards Committee in 1930. The film of pioneering days was stated to be 1.375-in. wide without qualification. Later, the same film apparently was considered to be 35 mm wide. The result is that the inch values are stated to the fifth place. Curiously enough, it appears that the dimension describing the pitch is regarded as being basically 0.187 in. in the English system. Accordingly, the metric equivalent is recorded to the fourth place. Even if films are designated 35mm or 16mm, they are not based completely on the metric system. All the PH22 films are hybrids, since they are designed to have 16 frames/ft for 35mm, 40 frames/ft for 16mm, and 80 frames/ft for 8mm film. These dimensions are tied to the use of the sprocket printer generally employed in the United States. Even today we have some trouble in engineering committees in choosing appropriate metric equivalents, and some apparent inconsistencies of dimensioning may still be found. In many cases it is possible to say that the conversions represent acceptable practice and that it is considered that the advantages of having round numbers in both systems outweigh the importance of the residual differences.

It may seem unusual in a country using the foot and inch system to pay a great deal of attention to the metric system. However, motion-picture equipment and film are made in many places all over the world. They are frequently used indiscriminately in combination and these combinations are expected to work together. In fact, they do, for motion-picture standards are among the oldest and most successful in the world.

A standard intended for both negative and positive films was finally adopted in November 1934, and is shown in Fig. 4. It is interesting to see that the tolerances, given only for width in 1930, now are extended to other dimensions, such as hole size, margin, and longitudinal pitch. This was a situation where a special effort was made to get closer tolerances for film used in cameras.

At this time, there was an attempt to eliminate the use of the old negative perforation, described by most users as "Bell & Howell," in favor of the new "positive" perforation. The standard shown in Fig. 4 was specified to be for negative and positive raw stock, thereby, in an attempt at simplification, setting a "universal perforation" as standard. This action considerably preceded the action of the 9th International Congress of Scientific and Applied Photography held in Paris, July 1935, at which time it was proposed that a single perforation be adopted on an international basis. In September 1936, the matter was discussed at Budapest in the meetings of the ISA. The war intervened and ended the matter. The Russians subsequently adopted the perforations with rectangular shape and rounded corners for both negative and positive films. These are the films of Type I and Type Ia tabulated in current proposals[14] of the ISO, which is the successor of the ISA.

However, the individual members of American industry had not asked for this change in practice and were reluctant to act upon the basis of these resolutions. The purchasing agents continued to purchase negative film with "Bell & Howell" perforations. Some European

standardizing bodies set standards which are *obligatory*, while American bodies *recommend* standards to which purchasers or manufacturers need not adhere. The standards merely describe the dimensions of the article which the customer has requested, in keeping with the long established democratic American practice. However, the standards are NOT purchase specifications, and the tolerances represent compromise values set somewhere between the perfection the user would like and the generous range of size the manufacturer would find more comfortable to produce. Actually, a reduction in the size of tolerances, if they are brought below the obvious values needed for a reasonable level of performance and interchangeability, constitutes a basis for competition between suppliers.

In that period of our history, American purchasers continued to order the negative film with the conventional "Bell & Howell" perforations that they had used previously. There were several reasons for their conservatism. One was the cost of getting new equipment after they had just accumulated a great number of cameras and printers. In addition, the libraries of "stock shots" and completed pictures that had been accumulated amounted to millions of feet. It seemed undesirable to go to a new film system using another perforation, which might interfere with the smooth operation of printing operations using the older negatives. Film of the current American standard was serving its purpose admirably.

This episode in the fortunes of an American standardizing body is an excellent example of the position occupied by standards in the United States. The standards do not have the force of law and neither manufacturers nor users are required to follow them. The individuals of the American motion-picture industry refused to follow where the SMPTE attempted to lead by publishing a standard after it had been adopted in committee. As a result of the "universal" standard being ignored, the Society bowed to the desires of the film users in the industry and restored the "Bell & Howell" negative perforation to the standards, where it is today.

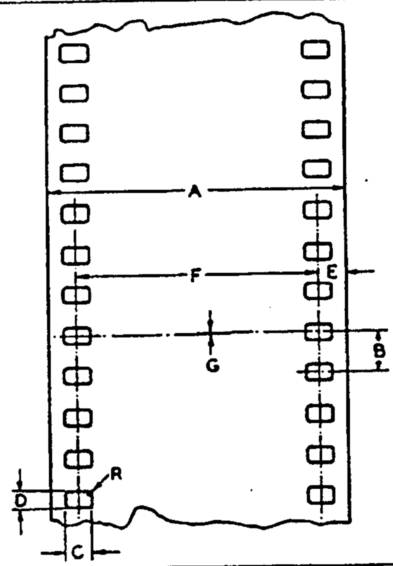
The SMPTE standards were reprinted in 1930 and in 1941 in the form of a booklet of American Standards approved during the period of informal cooperation that existed soon after the organization in 1928 of the American Standards Association. By 1938 the relationship became more formal and the format used in the publication of dimensional standards issued by the American Standards Association was similar to the present format (Fig. 5).

These early standards were very brief and, in fact, often stated things by implication. In 1941, the addition of notes became apparent. Until that time, there were few orienting comments. The standards had a formal and conventional structure which sometimes led to misunderstandings.[15] A particularly good example (and a potentially embarrassing item) was the case where Germans and Americans started to use opposite sides for the location of the soundtrack and emulsion for 16mm film![16]

After 1941, other orienting material, less vital but useful, appeared in appendices. The appendices were not regarded as a substantial part of the standard itself, but as material which would facilitate the use of the standard. Orienting discussions are useful and to a degree they are necessary. There are no textbooks in the field of motion-picture engineering. Accordingly, the notes are the only comments available or the only source of information for the casual reader other than material published by the sales service groups of the film manufacturers.

The preceding discussion has pointed out the way in which standards were written in an effort to help the user get good results. There is a limit as to how far an American group, working as a technical committee, can go in this con-

ASA Z22.1 (Sept. 20, 1930)	AMERICAN STANDARD For 35 mm Film CUTTING AND PERFORATING NEGATIVE AND POSITIVE RAW STOCK	SMPE DS35-1-1 *Adopted* Original: prior to 1928 This revision: 1936



	Millimeters	*Inch Equivalents*
A	35.00 +0.00 −0.05	1.378 +0.000 −0.002
B	4.750 ± 0.013	0.1870 ± 0.0005
*C***	2.794 ± 0.01	0.1100 ± 0.0004
*D***	1.98 ± 0.01	0.0780 ± 0.0004
E	3.40 ± 0.05	0.134 ± 0.002
F	28.17 ± 0.05	1.109 ± 0.002
G	Nct > 0.025	Not > 0.001
*L**	475.00 ± 0.38	18.700 ± 0.015
*R***	0.5	0.020

* *L* = the length of any 100 consecutive perforation intervals.

** This single style of perforation, known as the SMPE perforation, shall be used for all 35 mm. film. It is the same as the perforation known prior to July 14, 1933, as the standard positive perforation.

These dimensions and tolerances apply to the material immediately after cutting and perforating.

Fig. 5. Dimensions for 35mm film as given in 1938 when the format of the American Standards Association was developing toward its present shape.

nection. The American Standards Assn. which publishes documents of this kind, is a voluntary association and the standards are not obligatory, as noted above. The standard does not tell him what he can have or must take. Surely, the dimensions must have tolerances chosen so that interchangeability is assured. The standards must also describe the needs of reasonably well-made equipment in current use and its performance. The performance of the resulting film-camera combination that conforms to these standards must be acceptable. However, the attainment of substantial perfection must be allowed to remain a competitive matter among manufacturers. In any event, it may be said that there is no difference if the customer cannot perceive it in the behavior of the products concerned!

"Universal" Perforations

Most prints made in American laboratories have been made on continuous

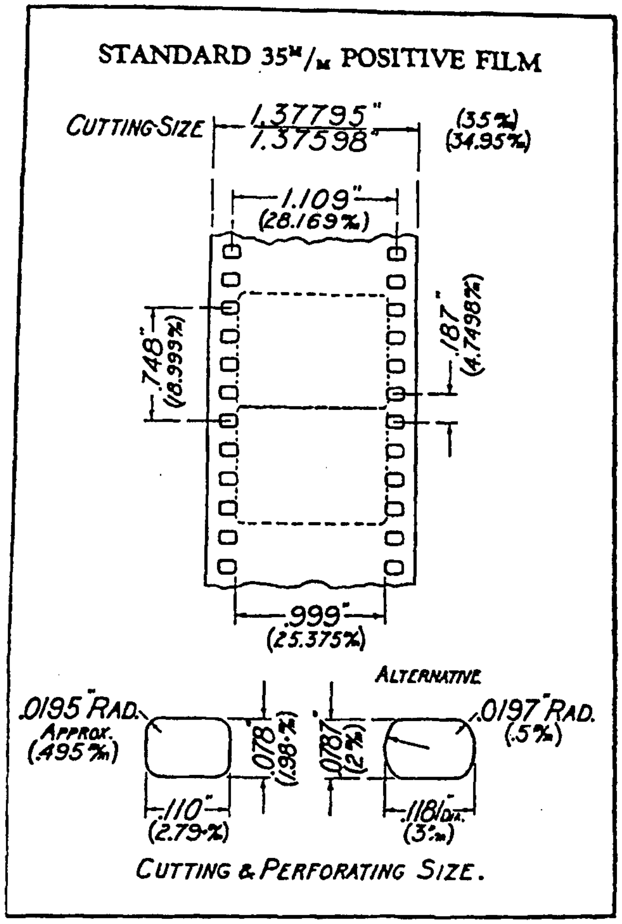


Fig. 6. Dimensions for 35mm film as given in 1938 in the form used for positive film.

sprocket-printers, quite unlike the situation in Europe, where step printers are generally employed to make prints. Sprocket printers operate easily and give good results when they are used to make prints by a single exposure.

However, the uniformity of positioning in this printing process does not give consistently reliable results for techniques requiring two or more exposures. When Republic Pictures Corp. began the manufacture of Trucolor prints on either side of a special film stock which had emulsion on both sides, the use of optical printers was considered too expensive. Therefore, step-contact printers were used. Since the 0.073-in. height of the negative perforation was not the same as that of the 0.078-in. positive perforation, the situation was not improved. Relative movement could take place in a vertical direction, so a remedy was sought. It was found in the use of the "Dubray-Howell" (DH) perforation[17] for the print stock. This perforation had a height of 0.073 in., the same as that used for negative film, and a shape much like the perforations used for negative film, and a shape much like the perforations used for print film. Figure 7 shows the outline of the various perforations, for which the dimensions are given in thousandths of an inch. A printer pin that would fit the "Bell & Howell" perforation would also fit into the DH perforation even though it would make only point contact at the sides.

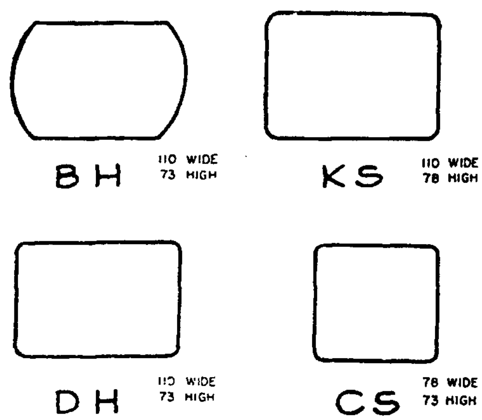


Fig. 7. Outlines of various forms of perforations for 35mm film.

A considerable amount of film thus perforated was printed on modified Duplex printers at Republic. Later, when a new color print film was made as an integral tripack and used more generally, the DH perforation was still employed. Today the most recent style of color print film still employs the DH perforation although it is not regarded as a universal perforation. Not all users are aware of the difference between the perforations on these color prints and the older black-and-white prints. Technicolor changed from the "Bell & Howell" perforation on their imbibition prints to the KS perforation late in 1950, so there is no concurrence in this field.

It is worth recalling that work done in 1937 bv the Film Dimensions Committee showed that the film perforated with DH holes gave accurate results and had an adequate projection life. A modified "Bell & Howell" perforation which had round corners was considered seriously for this purpose but was finally dropped.[18,19] This perforation resembles the 2mm X 3mm "continental" perforation of Chart 2 of the Standards of the Society, published in November 1934 (Fig. 6). The continental or 2mm X 3mm perforation had been an alternate form listed in the standards as a recognition of European practice. However, perforations of the continental shape were little used in America and the standard had been effectively superseded by April 1934.

Wide-Screen Processes, CinemaScope Perforation

In 1954, a new wide-screen system was announced.[20] This system did not use the wider films employed to produce the Grandeur pictures[21,22] of the 1930's. The new system used camera lenses with special optical properties which gave an anamorphic image on the film. This image, when rectified in projection, gave a more elongated rectangular image on the screen. The use of elongation obtained wider pictures, within the limitations of ceiling height and other structural features of theaters, and made it practical to project at higher overall magnifications. This system used film that could be processed on conventional 35mm equipment. This new film could be projected on projectors changed so slightly that conventional films could also be employed in them. The projector sprockets were changed so that they would handle the new film as well as the old.[23]

This development was furthered by devising a smaller perforation for the CinemaScope system. The new perforation resembled the DH perforation, but was only 0.078 in. wide. The space made available by narrowing the perforations was taken up by two magnetic stripes placed inside the lines of perforations and two other stripes were placed outside the line of perforations. Even with the added stripes, it was possible to make the projector aperture 0.912 in. wide. This dimension compares favorably with the 0.825-in. width used for the conventional projector aperture. Perforations of the various types are shown in Fig. 7, with the new CS at the lower right.

The height of the projector aperture used in the CinemaScope system is

greater than that of the conventional sound aperture, so there is a material gain in the use of available area for picture information aside from the apparent gain arising from anamorphosis. The actual heights are 0.600 in. for the sound aperture and 0.715 in. for the new aperture. Recently the use of all four magnetic tracks has decreased and the CinemaScope prints carry “magoptical” tracks which may be played either magnetically, or as photographic soundtracks as occasion demands. The picture aperture is sometimes changed also. A number of these schemes for new formats were studied[24] and used abroad.

Cinerama

Another system which gives a much wider picture had been announced a year previous to the presentation of CinemaScope. This earlier system, called Cinerama, used three cameras and three projectors to give a united wide image that created an illusion because of the great amount of peripheral vision that was made possible. The process was an outgrowth of the Fred Waller Flexible Gunnery Trainer[25] used to train aerial gunners to hit fast-moving air-borne targets. The realism achieved in the operation of this trainer was remarkable, and it was thought a civilian counterpart could produce results heretofore not achieved in the field of entertainment.

The film used in this process is conventional 35mm but, in terms of dimensions, it has an unusual feature. The frame is six perforations high. Ordinarily, the height of a 35mm motion-picture frame is four perforations, and the way the film is generally handled cancels some of the errors of perforating. The use of a frame six pitches high, when the film is perforated four pitches per frame might be expected to destroy the cancelling effect[26] and give rise to some unsteadiness. However, film is manufactured more accurately today than previously and the use of cancellation in projection is not a vital factor where the extreme accuracy of process photography is not needed. In fact, cancellation is not very effective if the errors of camera, printer, or projector are greater than the errors of perforation. The Cinemiracle process, which was evolved several years later, resembles Cinerama.

VistaVision and Technirama

These two systems produced a larger picture than that employed in the conventional 35mm system, but achieved it by employing a 35mm frame twice as big or eight perforations long. The film was moved horizontally, which explains the name of "lazy eight" that was sometimes applied to the VistaVision process. The prints at first were made by contact, and used for projection in especially equipped theaters. However, most negatives were printed optically in various 35mm formats used in more conventional projectors.

The advantages of these two systems were to be found in the use of film of traditional size, which is easily purchased and developed, and in the use of a large negative area. The use of film in the horizontal position had been tried several times before, but these systems were the only ones that reached commercial proportions. Printing from larger formats thus obtained in the negative leads to a reduction of grain in the print. This decrease in the effective granularity of the negative makes the use of larger negative formats attractive. One of the disadvantages of the VistaVision process possibly was connected with the comparative large acceleration which had to be used (especially in the projector) to move the 35mm film a distance of 1.496 in., compared to a distance of only 0.935 in. required for the 70mm format. Thus, the advance of the film needed for the "lazy eight" was 60% greater than that needed for the wider film. However, the area (or weight) of the 70mm film was 25% greater than that of the 35mm film VistaVision format.

CinemaScope 55

Film 55.625mm wide was employed in the camera for a while in order to achieve reduction of grain in 35mm prints having the CinemaScope format. However, there are no productions in the market today which use this format.

70mm Wide Screen Process

Other systems have been used in order to give the viewers a sense of participation, or to reduce the effect of graininess in the projected print. Among these are MGM Camera 65, Panavision, Super Technirama, and Todd A-0, all of which use 70mm release prints.[27]

There is one size of 65mm film in current use, which is employed as a negative film.[28] However, there are three types of 70mm films, only one of which is used currently for motion pictures. Obviously, caution must be used in ordering the proper film.

One 70mm film was derived from the old "Grandeur" film used in the 1930's and is not used for motion-picture work today. It is described by PH1.20-1963[29] as Type I and designated in that standard as something not intended to be used in motion-picture photography. It has a longitudinal pitch of 0.234 in. rather than the usual 0.187 in. It uses larger perforations than other films. Today this film is used mainly in recording instruments and a few styles of special-purpose data-recording cameras, some of which can be considered as motion-picture cameras, although not used in making entertainment films. These cameras are used in gathering data concerning measurements. Another size of film which conforms to PH1.20-1963, but is designated as Type II, was formerly described by a Military Standard. This Type II film has a margin of 0.079 in. and perforations of the usual KS conformation. It is used largely for aerographic purposes and for still pictures in the Graflex combat camera which is built for cassette loading with an expendable magazine.

The 70mm film described first, which is the one used today for current motion picture print[30], is new. It is unusual because it has the perforations of the 65mm negative[28] with extra film added to the region outside the perforations (as it were) in order to make room for several magnetic soundtracks. The picture frame is five perforations high. This arrangement was requested originally in order to get the desired proportions. Also. this time it was planned to make the prints in projection printers with considerable care in order to get maximum steadiness of image. The process of optical printing also allowed a calculated distortion of the image to be accomplished, the distortion offsetting that which might be expected to take place during later projection on curved screens, and at considerable angles of inclination. This procedure of making special prints was expected to give the least possible distortion of tall objects visible on the screen of a particular theater. Uncorrected prints are currently being made by contact on a sprocket printer, with satisfactory results. It is expected that there will soon be a new proposed standard for negative film to be printed by contact. Such a proposal will differ from the present one in that it will have a slightly different longitudinal pitch.

Amateur Movie Films--Small Films

The use of the old standard 35mm film has been supplemented to some extent by 70mm film which is used to produce bigger images, at a bigger cost. This procedure can be justified for certain pictures exploited in luxurious theaters.

Amateurs, obviously, cannot afford costly film for their home movies. This is the reason that when an amateur movie system was announced by Mees,[31] the 16mm size was chosen as a good compromise between cost and utility. In addition, there was another consideration in respect to protection from fire. It was thought that some small

operators might want to make 16mm film from 35mm film which, at that time was coated on flammable nitrate film base. The 16mm size could not economically be cut from perforated 35mm film, a fact which afforded a certain degree of protection against this contingency. It has been a strong tradition in the American film industry that 16mm and 8mm film must always be coated on safety film base.

The use of reversal processing obviated the need for making prints and thus kept prices low. In addition, the use of controlled second exposures in processing gave images which were uniform in density in spite of variations in exposure or emulsion thickness. The pictures were astonishingly free from graininess. All these advantages resulted in success for the 16mm system, which had not been attained by the 30 or more systems12 previously intended and exploited for amateur use.

The dimensional standards for this 16mm fil[33] were announced soon after the film was introduced. This was quite unlike the situation where 35mm film was standardized some time after commercial utilization. The dimensions of 16mm film have remained largely unchanged over the years, if we except the narrowing of the width, and the shortening of the pitch for professional camera original film. These changes had to be made to offset the effects of decreased shrinkage that took place when the film base was improved.

Actually, the "amateur" 16mm film has changed character. Very excellent equipment is made for this format which is employed extensively today as a medium for professional use. Today the amateur generally uses 8mm film; this smaller size was made possible by improvements in the graininess of emulsions. The dimensions of the film[34] have not changed much since they were published as DS8-1-1 and as the proposal for Z22.23 in 1938. However, the film actually came into use in 1932.

In recent years, 8mm projectors[35] have been provided with magnetic soundtracks[36-38] which later were standardized[39] with test films provided for them. There has also been talk of producing photographic sound on film of this size.

The cost of processing narrow films has been a problem, since the length is large compared to the area. Accordingly, the cost of labor and equipment required to handle it is greater than one would like. The problem was met in the 8mm system by making the camera film a "double 8" or 16mm in width. In the 16mm field, the 32mm print film[40] is analogous. Also, there is 35mm film perforated 32mm[41,42] which allows the laboratory to use its developing equipment to produce both 16mm and 35mm sizes. Eventually there will be a proposal for 35mm film to be perforated 8mm with five rows of perforations, which subsequently will be split to form four strips of 8mm prints.

In recent years, there has been much interest in new, small film formats with special reference to their use in education. Information on this subject is contained in sections on nontheatrical films and 8mm cinematography of the Progress Committee Reports for 1962, 1963, and 1964, in the May 1963, 1964 and 1965 issues of the Journal.

Problems of Printing

Thus far, the films described have been of considerably different sizes, and little mention has been made of films which differ only slightly from each other and serve in a special complementary relationship.

Such paired films are made up of a developed and edited negative, and the positive raw stock to be printed from it. Formerly, the original dimensions of the two films could have been the same at the start or at time of manufacture. The reason that this near identity of dimensions could be used was that the prints might have been made by a

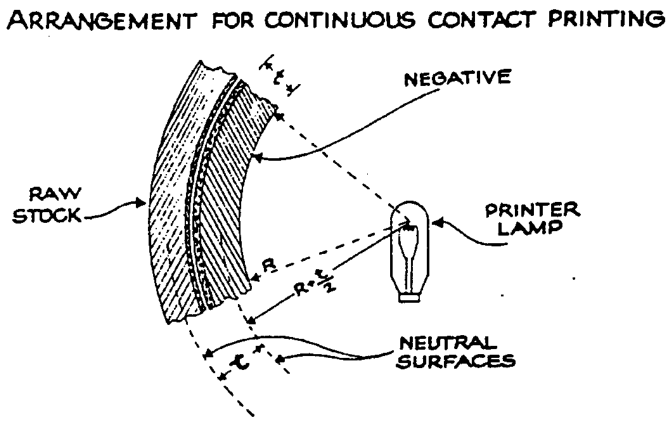


Fig. 8. Schematic of a sprocket printer showing the relationship that necessitates a shorter pitch if the negative is not to slip during exposure.

process wherein the separate frames were exposed one by one in a "discontinuous" process of step printing. In such a case, the exact size of the longitudinal pitch - within limits - would not matter. If printing was done by a continuous process, it would be done from negatives that had shrunk during the time normally used for editing. Accordingly, the negative had attained a shrinkage which satisfied the demands imposed by the geometry of the process.

Continuous printing is generally done on a device having a sprocket, as shown schematically in Fig. 8. This arrangement requires that the pitch of the negative, which is placed on the inside of the pair of films, must be shorter than the pitch of the print stock. The latter is, of course, the one placed on the outside of the pair of films.

If the proper difference of pitches were not accomplished, the actual surface speed of the films, which are fed over the printing drum by the sprocket teeth pitch by pitch, would not be the same. In that case, there would be differential movement between the two pieces of film. Slippage would take place. The result would be blurring of outlines, particularly parallel horizontal lines, and a general feeling on the part of an observer that sharpness had been lost. Sometimes the adjustment of lengths that occurs when there is a poor matching of pitches is delayed for several frames. A rather large jump is the result. Not only does slip affect the quality of pictures, but it has a bad effect upon sound as well.

The sprocket teeth are not indicated in Fig. 8, but the neutral surfaces of the film are shown. These are the regions about which bending takes place without a change taking place in their length. These neutral planes are the ones from which calculations are made. In bent film, the portion of film lying inside the neutral surface is slightly compressed, and the portion outside is slightly stretched.

For best results, the difference in pitch can be calculated if we know the thickness of the film and the dimensions of the printing sprocket. The difference in pitch which gives nonslip printing is the ratio of the thickness of the film to the radius of the sprocket corrected for the added film thickness. The optimum value is close to 0.3% for a sprocket 1 ft in circumference. Observe that the ratio is, more precisely, the film thick

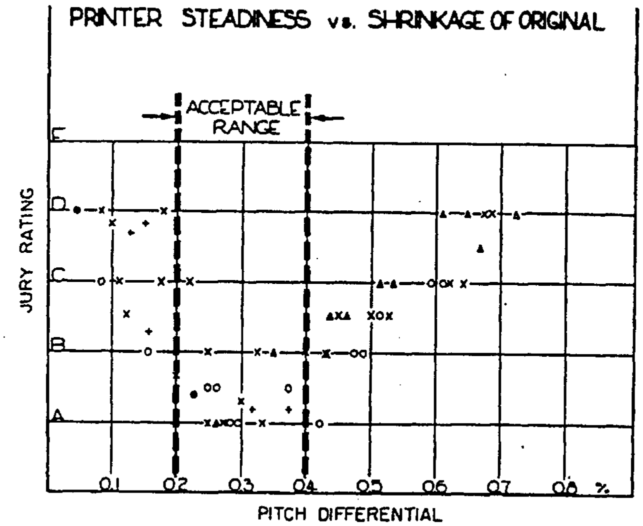


Fig. 9. Relationship between the pitch-differential of positive-negative pair and the steadiness of the resultant prints.

ness divided by the value representing the radius of the base circle increased by half the thickness of the inner film.

Negatives made with the safety film base used today do not shrink 0.3% while stored during the time needed for editing. In fact, since 1950, the negatives generally used do not shrink the 0.2% that would give tolerable results at the lower level of pitch differential. Some corrective action is needed. Accordingly, the pitch of negatives made on the improved safety film bases available today, must be shortened ahead of time.[43]

The amount of shortening that is necessary is indicated in Fig. 9 which shows an experimental verification of the value required by geometric theory.[44] Streiffert's later data,[45] when plotted, gave similar results. These data describe measurements of flutter made on sound recordings.

The ordinates in Fig. 9 show the ratings given by a jury for a number of prints made from negatives of different pitches. The ratings are actually demerits, and hence, the lower the value the better the performance. The demerits are stated on a five-point scale, where E represents the worst prints ever seen and A represents the best.

In some of the experiments, the negatives were perforated to a shorter pitch than the normal value; in other cases, the difference in pitch was secured by aging procedures. In all cases, the pitch differential in percentage values is shown as abscissae. The dotted vertical lines show the acceptable range of privileged prior opinion of individuals examining prints in review rooms. The range of values seems well chosen and the mean agrees with the value chosen from geometric considerations. There is a certain amount of scatter in the location of the points, but the minimum value is easily decided upon and is very close to the calculated value of 0.3%. The results show a loss of one letter-rating point, going from 0.3% pitch differential up to 0.4%, or down to a differential of 0.2%.

A description of this relationship between positive and negative films is given briefly in the Appendix of Per

forating Standards. An example is to be found among the several proposed Standards published in the September 1963 issue of the *Journal.* The standards cited are for 35mm film perforated KS-1870, and for 35mm film perforated DH-1870. These are examples of print stock.[46,47] The same issue of the *Journal* contains a proposal for 35mm film perforated BH-1866[48] which is the best example of film used for camera negatives.

The task of identifying film perforations properly has grown more difficult as the variety of perforation types has increased. The use of identifying letters such as BH and KS used in the paragraphs above was started recently."

The system is being extended so as to describe the more elaborate special-purpose films frequently used to decrease the cost of printing 16mm or 8mm film, or to decrease the need for another set of developing tanks in the laboratory.

Problems of Developing and Later Use

Vexatious problems often arise when someone who sets up a new venture in picture-taking does not consider the subsequent steps. For instance, 35mm film perforated 32mm, cannot be developed on 35mm machines made with sprockets designed to fit 35mm film perforated KS-1870; a sprocketless developing machine must be used. If this machine is not available locally, then the exposed material must be shipped away for development. The added expense may not be a crucial matter, but the delay is often very troublesome.

Similar troubles could be encountered in the use of 70mm film existing in several formats. Indeed. while there is a considerable choice of equipment for motion-picture films of conventional width and frame-size, there is little choice (and sometimes none) for equipment designed to handle the unusual format. Sometimes equipment has to be made to special order, which is an expensive and slow process.

Summary

In this paper the authors have attempted to show the progress of the art of making motion pictures, and the problems of standardizing the dimensions of the resultant products. In the beginning, there was a tendency to produce films of different sizes because of lack of contact between the entrepreneurs,[50] or even because of a kind of pride in having something different. However, most of the recent changes have been made with good reason. One example is the saving of area in the CinemaScope process, which also permits peripheral viewing of the projected image. Another example of a - defensible change is the use of the 70mm process to reduce the effect of graininess observed in the projected print, or to get more light on the screen. As a result of the adoption of these new sizes, there are a number of sizes available to designers who want to develop equipment for new purposes.

In addition to a knowledge of the geometry underlying the design of a sprocket printer, a good understanding of the printing operation requires some knowledge of the changes taking place in the size of film with the passage of time and also with changing conditions of storage. For example, film can undergo changes that are reversible, as when it is heated. Under these conditions, it expands; when it is cooled, the film contracts again as do most other materials. Similar changes in dimensions take place when film is taken from surroundings of a given humidity and then put into a moister atmosphere. The film will swell. just as wood does, and will shrink when it is changed to drier surroundings. The size of these reversible changes can be typified by making measurements and then calculating the thermal and humidity coefficients. These values give the fractional change in size in terms of

percentage change per degree Fahrenheit or changes with respect to the percentage relative humidity.[51]

There are also changes in size which take place over a greater length of time because the solvents have left the film. This change in size is, of course, shrinkage. This is an irreversible change. The extent of long-term shrinkage has decreased over the years, but it still is a factor to be reckoned with if the operator intends to make prints from old negatives.[52-54]

Data about long-term shrinkage are also of interest in connection with projection practice. However, in current American practice, shrinkage is seldom so great that the operation of the projector is impaired. An exception can be found in unusual equipment (including cameras) where the film occupies too great a "wrap" around a sprocket thereby bringing into use more teeth than may be necessary. Arbitrarily, and as a start for discussion, the greatest number of teeth in engagement may be set at six. The engineering principles have been discussed[55] and set forth in a recommended practice[56] which should be consulted for quantitative discussion.

This paper outlines the need for dimensional accuracy and comments upon the notes and appendices to standards which serve as sources of information in a field where there are no textbooks.

Acknowledgment is made to many colleagues in the Film Dimensions Committee, in the industry, and in our own organizations who have helped us in this work.

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35mm	Z22.4–1941*	Mar. 1941 Aug. 1963[3]
Reel Spindles, 16mm	PH22.50–1960	Dec. 1952 Oct. 1960[4]
Release Prints, 35mm	Z22.55–1947*	Mar. 1948
Reversal Color Film Speed	PH22.146	Dec. 1964[1]
Safety Film	PH22.31–1958*	Jan. 1959
Scene Change Cue	PH22.89–1958*	June 1958[3] Sept. 1964[3]
Screen		
Brightness, 35mm Motion Pictures	PH22.39–1953	May 1953
Withdrawn 1964		July 1964[6]
35mm Indoor Theaters	PH22.124–1961	Sept. 1961
35mm Review Rooms	PH22.133–1963	June 1963
Drive-In Theaters (SMPTE Recommended Practice RP 12–1962)		July 1962
16mm Review Rooms	PH22.100–1955*	Feb. 1956
Sensitometric Strips (SMPTE Recommended Practice RP14–1964)		Apr. 1964
Splices, 16 & 8mm		
Laboratory Type	PH22.77–1952*	June 1952 Aug. 1964[1]
Projection Type	PH22.24–1952*	June 1952 Aug. 1964[1]
Spools, 8mm, 25-ft Capacity	PH22.107–1964	June 1964
Sprockets		
16mm (SMPTE Recommended Practice RP-1950)	R1963	Feb. 1950
35mm	PH22.35–1962	May 1962
Unsteadiness, High-Speed Camera (SMPTE Recommended Practice RP 17–1964)		May 1964

* Under Committee review. R—Reaffirmed.

† Film dimension titles show film width, perforation pitch (without the decimal point) and a code designation for the perforation shape—BH KS DH CS (Bell & Howell, Kodak Standard, Dubray-Howell, CinemaScope)—or number of rows of perforations (1R, 2R or 4R), depending on which is the significant factor.

[1] Proposed standard or recommended practice. [2] To be withdrawn. [3] Notice of intended withdrawal.

[4] Essential technical content is included in the early publication date. The later date lists editorial or nontechnical changes agreed to by SMPTE engineering committees and subsequently incorporated in a revision of the standard.

[5] Appendix A, Technical Information on Lamps Used for Testing and Reporting Data, was omitted from the September 1958 issue since it was incomplete. [6] Notice of approved withdrawal.

APPENDIX D

AMERICAN STANDARDS ASSOCIATION

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American Standard Dimensions for

35mm Motion-Picture Film, KS-1870

ASA
Reg. U.S. Pat. Off.
PH22.36–1964
Revision of PH22.36-1954
*UDC 778.5.771.5

1. Scope

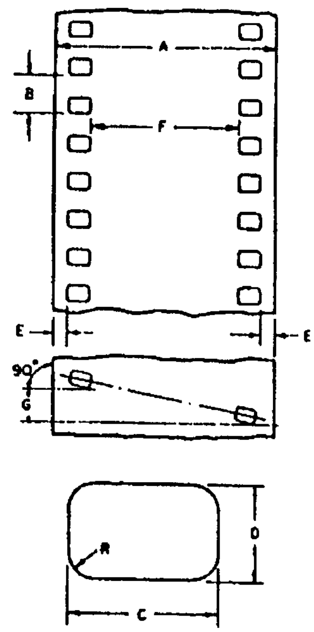
This standard specifies the cutting and perforating dimensions for 35mm motion-picture film with a KS-type perforation and a perforation pitch of 0.1870 in.

2. Dimensions

2.1 The dimensions shall be as given in the figure and table.

2.2 These dimensions apply to material immediately after cutting and perforating.

2.3 Dimension L represents the length of any 100 consecutive perforation pitch intervals.



	Dimensions	Inches	Millimeters
A	Film width	1.377 ± 0.001	34.975 ± 0.025
B	Perforation pitch	0.1870 ± 0.0005	4.750 ± 0.013
C	Perforation width	0.1100 ± 0.0004	2.794 ± 0.010
D	Perforation height	0.0780 ± 0.0004	1.981 ± 0.010
E	Edge to perforation	0.079 ± 0.002	2.01 ± 0.05
F	Width between perforations	0.999 ± 0.002	25.37 ± 0.05
G	Perforation skewness	0.001 max	0.03 max
L	100 consecutive perforation pitch intervals	18.700 ± 0.015	474.98 ± 0.38
R	Radius of perforation fillet	0.020 ± 0.001	0.51 ± 0.03

NOTES

1. The title of this standard was established by the application of a nomenclature system developed for all film dimension standards: Each title provides an indication of the film width, a code designation for the perforation shape (BH, KS, DH, or CS) or the number of rows of perforations (1R, 2R or 4R), depending upon which is the significant factor, and the perforation pitch without the decimal point.

2. The metric values in the table of dimensions are converted from the inch values in accordance with conversion principles outlined in American Standard Practice for Inch-Millimeter Conversion for Industrial Use, B48.1-1933 (reaffirmed in 1947).

Approved October 27, 1964 by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers, Inc.

*Universal Decimal Classification

Printed in U.S.A.
ASA1M1264/50

APPENDIX

(This Appendix is not a part of American Standard Dimensions for 35mm Motion-Picture Film, KS-1870, PH22.36-1964, but is included to facilitate its use.)

A1. The dimensions given in this standard represent the practice of film manufacturers in that the dimensions and tolerances are for film stock immediately after perforation. The punches and dies themselves are made to tolerances considerably smaller than those given, but since film is a plastic material, the dimensions of the slit and perforated film stock never agree exactly with the dimensions of the slitters, punches and dies. Film can shrink or swell due to loss or gain in moisture content or can shrink due to loss of solvent. These changes invariably result in changes in the dimensions during the life of the film. The change is generally uniform throughout a roll.

A2. It will be noted that among the various standards for slitting and perforating film stock there are often two standards which seem much alike in wording. The difference lies in the longitudinal pitch which is either 0.1870 in. or 0.1866 in. In general, the longer pitch is for print stock and the shorter pitch is for negative stock.

The choice of pitch for negative motion-picture films depends, within certain limits, on the type of printer to be used. Where step-printers are used, and the film is stationary when exposed, the choice of pitch is not strictly limited. Where the film moves continuously over a cylindrical surface at time of printing (sprocket-type printer), there are three major considerations involved in choosing the pitch. These considerations are: (1) the sprocket diameter, (2) the film thickness, (3) the film shrinkage and the rate at which shrinkage occurs.

Maximum steadiness and definition are secured on a sprocket-type printer when the negative stock is somewhat shorter in pitch than the positive stock in the approximate proportion of the thickness of the film to the radius of curvature. For printing on a 64-tooth 35mm sprocket (circumference of about 12 in.) with film 0.0055 to 0.0065 in. thick, the optimum pitch differential is 0.3 percent. The use of the ideal pitch differential for the negative would minimize slippage between the positive stock and negative during the printing operation, thus reducing the amount of blurring and jumping of horizontal lines in the picture or sound image. (This error is to be differentiated from the jump caused by nonuniformity of successive pitches, Dimension B.)

Experience has shown that the average pitch, Dimension L, of the negative can vary ± 0.1 percent from the ideal pitch, which is 0.3 percent shorter than the positive stock, without blurring of picture and sound image being easily detected.

For many years this desired difference in pitch was caused by the shrinkage of the negative film during processing and aging. Current film bases shrink less than the earlier ones and hence a shorter initial pitch becomes desirable. To satisfy this requirement for picture or sound negatives, it is common manufacturing practice to aim for a pitch value 0.2 percent shorter than the positive stock onto which they will be printed. The additional shrinkage that occurs during processing and the aging that takes place before the release prints are made then brings the pitch differential close to the optimum and desired value of 0.3 percent. Accordingly, the pitch chosen for the negative stock is 0.1866 in.

Low-shrink negative film perforated to these dimensions should not thereafter shrink appreciably more than 0.2 percent under normal use conditions, and for a reasonable life span, so that the optimum pitch differential from the positive stock of 0.3 ± 0.1 percent is maintained. (The film should be measured after equilibration with air at 70 F and 55 percent relative humidity or at the conditions prevailing at the time of perforating.)

A3. The uniformity of pitch, hole size, and margin (Dimensions B, C, D, and E) is an important variable affecting steadiness. Variations in these dimensions, from roll to roll, are of little significance compared to variations from one sprocket hole to the next. Actually it is the maximum variation from one sprocket hole to the next within any small group of consecutive perforations that is important.

American Standard Dimensions for

16mm Motion-Picture Film, 2R-3000

Reg. U. S. Pat. Off.

PH22.5—1964

Revision of PH22.5-1953

*UDC 778.5

1. Scope

This standard specifies the cutting and perforating dimensions for 16mm motion-picture film with perforations along both edges and a perforation pitch of 0.3000 in.

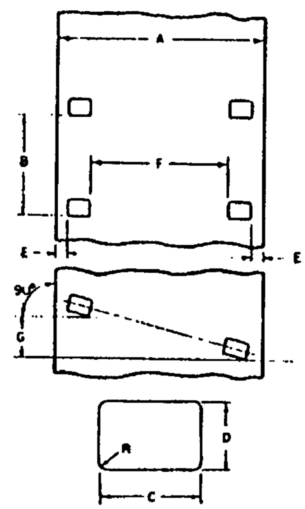
2. Dimensions

2.1 The dimensions shall be as given in the figure and table.

2.2 These dimensions pertain to a safety film as defined in Appendix A5.

2.3 These dimensions apply to material immediately after cutting and perforating.

2.4 Dimension L represents the length of any 100 consecutive perforation pitch intervals.



	Dimensions	Inches	Millimeters
A	Film width	0.628 ± 0.001	15.95 ± 0.03
B	Perforation pitch	0.3000 ± 0.0005	7.620 ± 0.013
C	Perforation width	0.0720 ± 0.0004	1.829 ± 0.010
D	Perforation height	0.0500 ± 0.0004	1.270 ± 0.010
E	Edge to perforation	0.0355 ± 0.0020	0.902 ± 0.051
F	Width between perforations	0.413 ± 0.001	10.49 ± 0.03
G	Perforation skewness	0.001 max	0.03 max
L	100 consecutive perforation pitch intervals	30.00 ± 0.03	762.0 ± 0.8
R	Radius of perforation fillet	0.010 ± 0.001	0.25 ± 0.03

NOTE 1: The title of this standard was established by the application of a nomenclature system developed for all film dimension standards. Each title provides an indication of the film width, a code designation for the perforation shape (BH, KS, DH, or CS) or the number of rows of perforations (1R, 2R or 4R), depending upon which is the significant factor, and the perforation pitch without the decimal point.

NOTE 2: The metric values in the table of dimensions are converted from the inch values in accordance with conversion principles outlined in American Standard Practice for Inch-Millimeter Conversion for Industrial Use, B48.1-1933 (Reaffirmed 1947).

Approved December 2, 1964, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers, Inc.

*Universal Decimal Classification

Printed in USA
ASA1M1065/40

Appendix

(This Appendix is not a part of American Standard Dimensions for 16mm Motion-Picture Film, 28 3000, PH22.5-1964, but is included to facilitate its use.)

A1. The dimensions given in this standard represent the practice of film manufacturers in that the dimensions and tolerances are for film stock immediately after perforation. The punches and dies themselves are made to tolerances considerably smaller than those given, but since film is a plastic material the dimensions of the slit and perforated film stock never agree exactly with the dimensions of the slitters, punches and dies. Film can shrink or swell due to loss or gain in moisture content or can shrink due to loss of solvent. These changes invariably result in changes in the dimensions during the life of the film. The change is generally uniform throughout a roll.

A2. It will be noted that among the various standards for slitting and perforating film stock there are often two standards which seem much alike in wording. The difference lies in the longitudinal pitch which is either 0.2994 in. or 0.3000 in. In general, the longer pitch is for print stock and the shorter pitch is for negative stock.

The choice of pitch for negative motion-picture films depends, within certain limits, on the type of printer to be used. Where step-printers are used, and the film is stationary when exposed, the choice of pitch is not strictly limited. Where the film moves continuously over a cylindrical surface at time of printing (sprocket-type printer), there are three major considerations involved in choosing the pitch. These considerations are: (1) the sprocket diameter, (2) the film thickness, (3) the film shrinkage and the rate at which shrinkage occurs.

Maximum steadiness and definition are secured on a sprocket-type printer when the negative stock is somewhat shorter in pitch than the positive stock in the approximate proportion of the thickness of the film to the radius of curvature. For printing on a 40-tooth 16mm sprocket (circumference of about 12 in.) with film 0.0055 to 0.0065 in. thick, the optimum pitch differential is 0.3 percent. The use of the ideal pitch differential for the negative would minimize slippage between the positive stock and negative during the printing operation, thus reducing the amount of blurring and jumping of horizontal lines in the picture or sound image. (This error is to be differentiated from the jump caused by nonuniformity of successive pitches, Dimension B.)

Experience has shown that the average pitch of the negative can vary ± 0.1 percent from the ideal pitch, which is 0.3 percent shorter than the positive stock, without blurring of picture and sound image being easily detected.

For many years this desired difference in pitch was caused by the shrinkage of the negative film during processing and aging. Current film bases shrink less than the earlier ones and hence a shorter initial pitch becomes desirable. To satisfy this requirement for picture- or sound-negatives, it is common manufacturing practice to aim for a pitch value 0.2 percent shorter than the positive stock onto which they will be printed. The additional shrinkage that occurs during processing and the aging that takes place before the release prints are made then bring the pitch differential close to the optimum and desired value of 0.3 percent. Accordingly, the pitch chosen for the negative stock is 0.2994 in.

Low-shrink negative film perforated to these dimensions should not thereafter shrink appreciably more than 0.2 percent under normal use conditions, and for a reasonable life span, so that the optimum pitch differential from the positive stock of 0.3 ± 0.1 percent is maintained. (The film should be measured after equilibration with air at 70 F and 55 percent relative humidity or at the conditions prevailing at the time of perforating.)

A3. The uniformity of pitch, hole size, and margin (Dimensions B, C, D, and E) is an important variable affecting steadiness. Variations in these dimensions, from roll to roll, are of little significance compared to variations from one sprocket hole to the next. Actually it is the maximum variation from one sprocket hole to the next within any small group of consecutive perforations that is important.

A4. The optimum width for 16mm film (which often goes through channels of fixed size) is controlled by the shrinkage characteristics of the films involved. Thus in times past there have been standards for the width of 16mm stock of the "usual" shrinkage and for stock of "low shrinkage" characteristics. The purpose was to obtain films of approximately the same width regardless of the type of film base during their useful life. This standard is based on the values adopted to "low-shrink" film base since nearly all films now manufactured in the U.S. meet the definition noted below.

For the purpose of choice of width, low-shrinkage film base is film base which when coated with emulsion and any other normal coating treatment, perforated, kept in the manufacturer's normal commercial packings for six months at 65 to 75 F, exposed, processed and stored exposed to air for a period not to exceed 30 days at 65 to 75 F and 50 to 60 percent relative humidity, and measured under like conditions of temperature and humidity, shall have shrunk not more than 0.2 percent from its original dimension at the time of perforating.

This definition of low-shrinkage film stock has been found by experience to be useful as a guide to film manufacturers in slitting their stock. Departure from this definition shall not be cause for rejection of the stock. Note that this definition of shrinkage differs from the criterion applying to the choice of longitudinal pitch, where greater periods of time are involved and where short-time tests can be deceptive.

Allowance has been made in arriving at these values for the common tendency of film to expand when exposed to high relative humidity. Allowance should be made for this factor in equipment design and in no case should 16mm equipment fail to accommodate a film of 0.630-in. width.

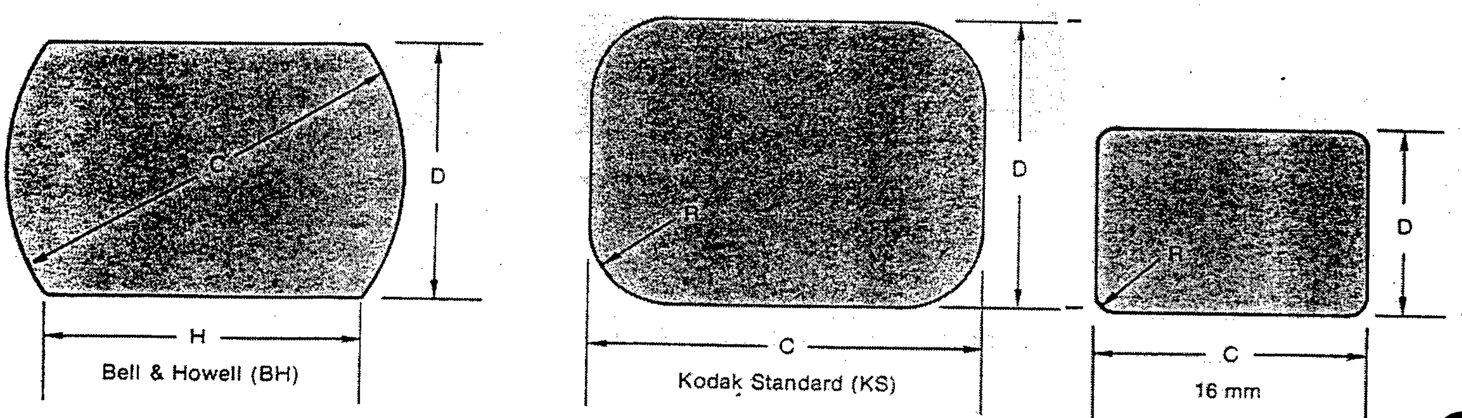
A5. This film is to be made on safety base complying with American Standard Specifications for Safety Photographic Film, PH1.25-1956 (Reaffirmed 1962).

APPENDIX E

PERFORATION DIMENSIONS

The following excerpts are reproduced by permission of Eastman Kodak Company. Copies of publication P-29, Technical Data on Film Specification Numbers, Spools, Cores, Dimensions and Perforations, may be obtained from Eastman Kodak Company, Department 454, 343 State Street, Rochester, New York 14650.

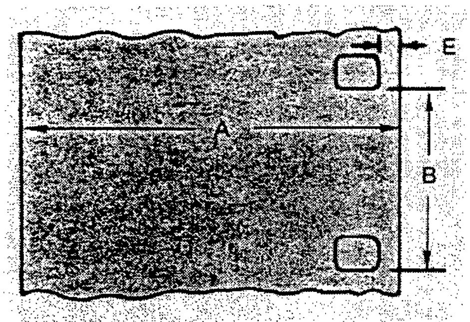
PERFORATION DIMENSIONS
16 mm—35 mm—70 mm



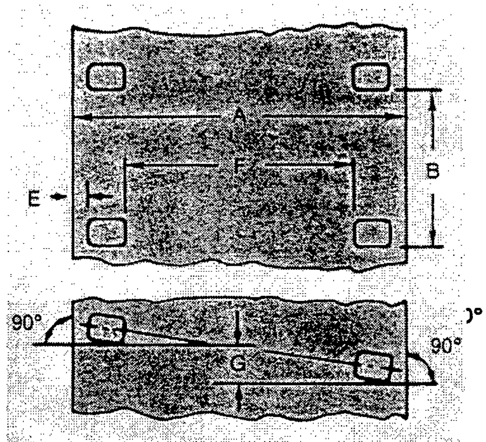
Perforation Type								
Dimension	Bell & Howell		Kodak Standard		16 Millimeter		Tolerances ±	
	Inches	mm	Inches	mm	Inches	mm	Inches	mm
C	0.110	2.794	0.110	2.794	0.072	1.829	0.0004	0.010
D	0.073	1.854	0.078	1.981	0.050	1.270	0.0004	0.010
H*	0.082	2.08						
R			0.020	0.51	0.010	0.25	0.001	0.03

*Dimension H is a calculated value.

FILM DIMENSIONS, 16 mm



Perforated one edge

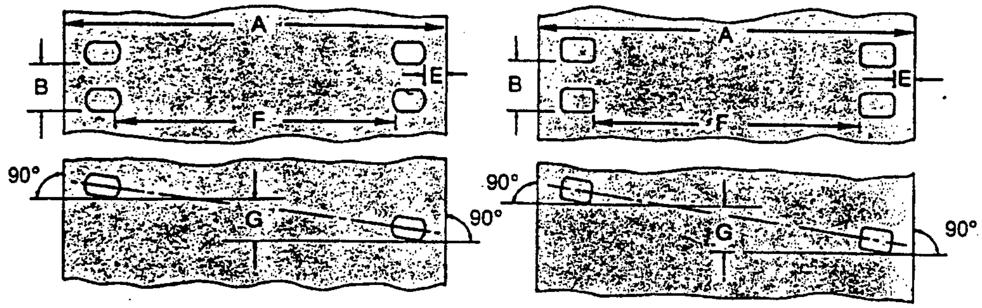


Perforated two edges

Perforation Type and ANSI Number										
Dimension	1R-2994 (PH22.109)		1R-3000 (PH22.12)		2R-2994 (PH22.110)		2R-3000 (PH22.5)		Tolerances ±	
	Inches	mm	Inches	mm	Inches	mm	Inches	mm	Inches	mm
A*	0.628	15.95	0.628	15.95	0.628	15.95	0.628	15.95	0.001	0.03
B	0.2994	7.605	0.3000	7.620	0.2994	7.605	0.3000	7.620	0.0005	0.013
E	0.0355	0.902	0.0355	0.902	0.0355	0.902	0.0355	0.902	0.0020	0.051
F					0.413	10.49	0.413	10.49	0.001	0.03
G (max)					0.001	0.03	0.001	0.03	—	—
L†	29.94	760.5	30.00	762.0	29.94	760.5	30.00	762.0	0.03	0.8

*This dimension also represents the unperforated width.
†This dimension represents the length of any 100 consecutive perforation intervals.

FILM DIMENSIONS, 35 mm



Perforation Type and ANSI Number										
Dimension	BH-1866 (PH22.93)		BH-1870 (PH22.34)		KS-1866 (PH22.139)		KS-1870 (PH22.36)		Tolerances ±	
	Inches	mm	Inches	mm	Inches	mm	Inches	mm	Inches	mm
A*	1.377	34.975	1.377	34.975	1.377	34.975	1.377	34.975	0.001	0.025
B	0.1866	4.74	0.1870	4.75	0.1866	4.740	0.1870	4.750	0.0005	0.013
E	0.079	2.01	0.079	2.01	0.079	2.01	0.079	2.01	0.002	0.05
F	0.999	25.37	0.999	25.37	0.999	25.37	0.999	25.37	0.002	0.05
G (max)	0.001	0.03	0.001	0.03	0.001	0.03	0.001	0.03	—	—
L†	18.66	474.00	18.70	474.98	18.66	474.00	18.70	474.98	0.015	0.38

Perforation Type and ANSI Number						
Dimension	Perf. 32 mm, 2R-2994 (PH22.73)		Perf. 32 mm, 2R-3000 (PH22.138)		Tolerances ±	
	Inches	mm	Inches	mm	Inches	mm
A*	1.377	34.98	1.377	34.98	0.001	0.03
B	0.2994	7.605	0.3000	7.620	0.0005	0.013
E	0.096	2.44	0.096	2.44	0.002	0.05
F	1.041	26.44	1.041	26.44	0.002	0.05
G (max)	0.001	0.03	0.001	0.03	—	—
L†	29.94	760.5	30.00	762.0	0.03	0.8

*This dimension also represents the unperforated width.
†This dimension represents the length of any 100 consecutive perforation intervals.